INTERIM REPORT:
MOUNTAIN PINE BEETLE EVALUATION
PONDEROSA PINE STAND RISK RATING USING GROUND AND AERIAL PHOTOGRAPHIC SURVEYS

1981

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Thesis/Report
Lessard

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FOREST PEST MANAGEMENT

United States Department of Agriculture

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Forest Pest Management
Denver, Colorado

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Ponderosa Pine Stand Risk Rating
Using Ground and Aerial
Photographic Surveys

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by

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INTRODUCTION

A procedure for risk rating ponderosa pine stands for mountain pine beetle susceptibility is available for the Black Hills of South Dakota and Wyoming (Stevens, et al 1980). The procedure uses three stand parameters to evaluate risk:

1. Stand structure
2. Average stand diameter
3. Average stand density (Basal Area)

Obtaining estimates of stand susceptibility over large, often inaccessible, acreages of forest land is a difficult task. Procedures are available using large scale photography for measuring stand parameters necessary for risk rating (Avery, 1966; Aldrich and Norick, 1969; Heller and Sader, 1980).

The objectives of this evaluation were to:

1. Evaluate the current risk rating procedure in the Black Hills (Stevens, et al 1980);

2. Evaluate large scale photographic techniques for risk rating;

3. Evaluate other stand/tree parameters which may contribute to stand/tree susceptibility to mountain pine beetle.

METHODS

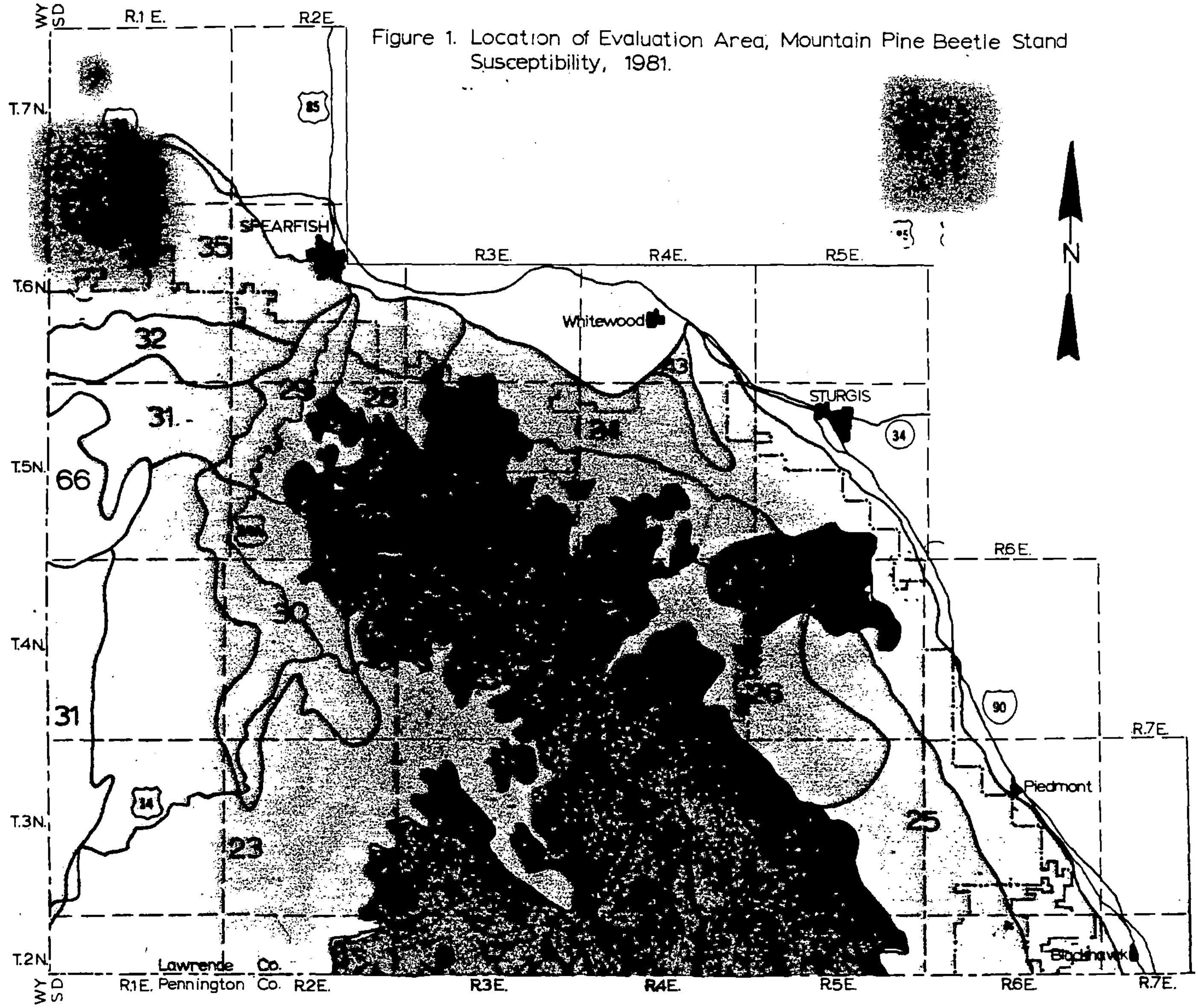
Evaluation Area

The evaluation area covers approximately 450,000 acres of ponderosa pine type east of the Wyoming-South Dakota State line; north of the Pennington County line in Lawrence and Meade Counties, South Dakota; and south and west of Highways 90 and 14 (Figure 1). The area encompasses all, or portions of, 25 Ecological Land Units (ELU's) on three major geological formations in the northern Black Hills (Table 1).

Table 1. Major Geologic Formations and Associated Ecological Land Units in the Evaluation Area

Geologic Formation	ELU #
Limestone Plateau	23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 35
Volcanic Mountains	60, 61, 62, 63, 64, 65, 66
Crystalline Basin	8, 9, 11, 12, 13, 14, 15

Figure 1. Location of Evaluation Area, Mountain Pine Beetle Stand Susceptibility, 1981.



NORTHERN THIRD BLACK HILLS NATIONAL FOREST, SOUTH DAKOTA.

KEY

Ecological formations
Limestone plateau
Volcanic mountains
Crystalline basin
Ecological land units (61)
County line
Forest boundary

Stratification

The entire evaluation area contained three primary layers of stratification based on:

1. Major geologic formation

    a. Limestone Plateau
    b. Crystalline Basin
    c. Volcanic Mountains

2. Stand

    - by structure

    a. single story
    b. multi-story

    - by crown closure

    a. 0-25%
    b. 25-50%
    c. 50-75%
    d. 75-100%

3. MPB Infestation Intensity 1/

    a. endemic $\leq$ 1.0 trees per 10 acres
    b. light 1.1 - 5.0 trees per 10 acres
    c. moderate 5.1 - 25.0 trees per 10 acres
    d. heavy > 25 trees per 10 acres

Initial stratification by intensity classification was based on aerial reconnaissance survey estimates in July 1981.

Photo Acquisition

Photography was 9 inch x 9 inch format, true color (SO-397) transparencies at a scale of 1:6,000. Photo coverage was 100% of stands randomly selected within strata.

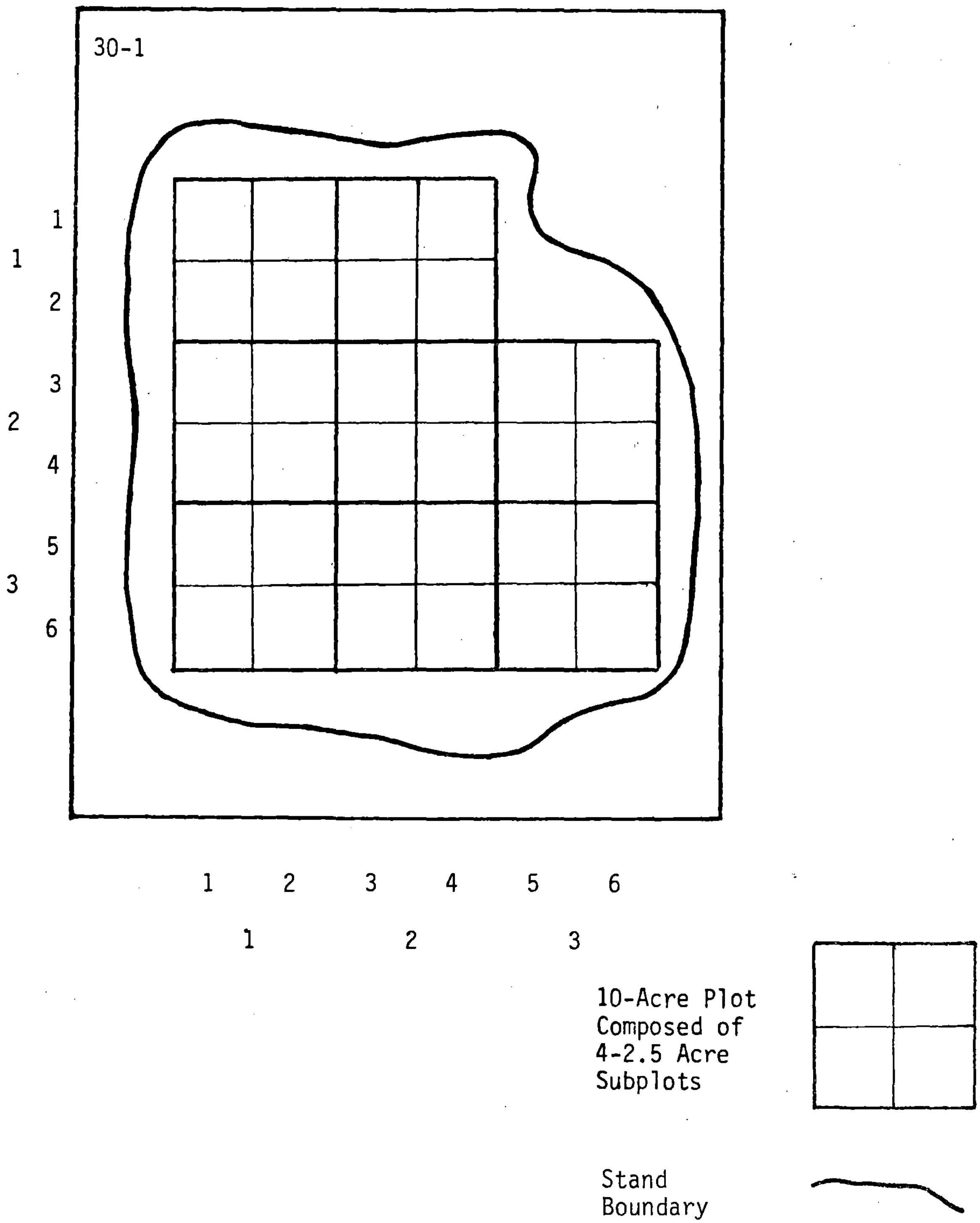
Photo Interpretation

Each stand was divided into 10-acre plots, subdivided into 2.5-acre subplots and indexed (Figure 2). All 10-acre plots were contained within the boundaries of the sampled stand. All subplots within a plot appeared visually to constitute similar stand conditions. Depending on stand size, the minimum number of 10-acre plots was three per stand and the maximum ten per stand.

1/ Intensity classifications have been established solely for this evaluation.

Figure 2 -- Layout of 2.5-Acre Subplots and 10-Acre Plots in a Stand

ELU - Stand 30-1



On each 2.5-acre subplot, the following data were recorded:

1. Crown diameter: Crown diameter was measured to the nearest foot on ten representative trees on each subplot. Each of these trees were circled and labeled on an acetate overlay of the photo plot. Procedures for estimating crown diameter are given in Appendix B (Avery, 1966).

2. Crown closure: Procedures for estimating crown closure are given in Appendix B (Avery, 1966).

3. Stand structure: Stands were classified as 2-or more storied if the overstory contains more than 30% but less than 70% of the total crown closure for the stand.

4. Total number of current faders.

Once all photo plots were interpreted, each 2.5 acre subplot was restratified by mountain pine beetle infestation intensity. Restratification was necessary to obtain a more accurate estimate of trees per acre infested within a stand.

Ground Truth

Using the three major layers of stratification (Geologic formation x stand x infestation intensity; 3x2x4x4), 96 strata were identified. In each of the 96 strata, an attempt was made to select two 2.5-acre subplots for ground truth (192 total ground truth plots). Since all strata were not represented on the photography, only 69 subplots were selected for ground truth. On each subplot, the following data were recorded:

1. Total number of ponderosa pine trees by infestation class (3.1 inch lower diameter limit)

   a. green uninfested
   b. green infested
   c. 1-year old infested
   d. 2-year old infested
   e. snag (> 2-year old infested)

2. Total number of other tree species (d.b.h. to the nearest 0.1 inch)

3. Tree diameter (d.b.h. to the nearest 0.1 inch)

4. Slope (%) and aspect (degrees)

5. Age and height of 3 dominant or codominant trees

6. Crown ratio of all green infested and 1-year old infested ponderosa pines, a minimum of ten green uninfested ponderosa pines, and the ten trees interpreted for crown diameter. For each infested ponderosa pine, a tree of equivalent diameter closest to the infested tree was measured.

Ground Plot Selection

Selection of ground truth plots was accomplished in two steps. The first step selected two stands per sampled stratum based on the entire photo interpretation count. The second step selected one 2.5-acre subplot within each stand. Each step selected on probabilities proportional to size (PPS).

RESULTS AND DISCUSSION

The three primary objectives of this evaluation will be discussed separately.

Objective 1 - Evaluate the current risk rating guide in the Black Hills (Stevens, et al 1980).

The risk rating guide does not provide a definition of risk. These were underlying problems with the guide noted prior to field evaluation. The first concern was the qualitative aspect of low, moderate, and high risk. Probability of infestation and tree loss cannot be determined for the stand being evaluated using this guide. Two major components of any risk rating guide are:

1. Probability of infestation of a stand in a given time period

2. Probability of tree losses, over time, once the stand becomes infested.

Quantitative probabilities can be assigned to stands in the Black Hills based on geologic formation, stand structure, and numbers of trees per acre by diameter class. Data from this evaluation are currently being analyzed by Walt Cole and Gene Amman, Intermountain Forest and Range Experiment Station.[2]

The second concern involves the parameters used by Stevens, et al (1980) to evaluate risk. Ground evaluations over the past three years indicated that the exception to Stevens, et al (1980) were as prevalent as the rule. Data from this evaluation confirmed this expectation.

To assess basal area as a factor in stand risk, linear regression analysis was used to predict trees per acre infested from 1979-81 as a function of green stand basal area in 1979. The regression analysis was computed by geologic strata. The coefficient of determination (r^2) for each strata are given in Table 2.

2/ The results will be presented in a suitable journal or Station paper.

Table 2. Coefficients of Determination (r^2) for Linear Regression of Trees Per Acre Infested by the Mountain Pine Beetle as a Function of Green Stand Basal Area by Geologic Strata.

Geologic Strata	r^2
Limestone Plateau	0.14
Volcanic Mountains	0.002
Crystalline Basin	0.03

The direct relationship suggested by Stevens, et al (1980), low risk < 80 BA, moderate risk 80-150 BA and high risk > 150 BA, was not confirmed in this evaluation. A step-wise regression comparing infestation by basal area in each diameter class is being investigated.

Stevens, et al (1980) suggested a direct relationship between average stand diameter and risk to mountain pine beetle infestation - low risk < 6 inches, moderate risk 6-10 inches, high risk > 10 inches. Again, this relationship was not confirmed in this evaluation. Table 3 provides a summary of probability distributions by diameter class for green stand in 1979 and trees infested 1979-81 by geologic strata.

Table 3. Probability Distributions by Diameter Class for Green Stand in 1979 and Infested Trees, 1979-81, by Geologic Strata

Diameter Class (inches)	Geologic Strata: Limestone Plateau		Volcanic Mountains		Crystalline Basin	
	Green Stand	Infested	Green Stand	Infested	Green Stand	Infested
3.1 - 5.0	.115	.018	.056	.072	.188	.030
5.1 - 7.0	.183	.125	.182	.261	.256	.167
7.1 - 9.0	.218	.268	.274	.297	.149	.275
9.1 - 11.0	.199	.302	.167	.178	.107	.214
11.1 - 13.0	.125	.161	.145	.120	.111	.157
13.1 - 15.0	.080	.070	.091	.034	.089	.079
15.1 - 17.0	.040	.036	.047	.024	.064	.057
17.1 - 19.0	.025	.014	.030	.008	.026	.020
> 19.0	.014	.007	.008	.006	.010	.003

Probability distributions are graphically displayed in Figures 3-5 for each of the three geologic strata. Without taking into account infestation intensity, there are diameter ranges in which the probability of attack exceeds the probability of occurrence of green trees. These ranges and probabilities are displayed in Table 4.

Figure 3. Probability Distributions by Diameter Class for Green Stand in 1979 and Infested Trees, 1979-81, Limestone Plateau

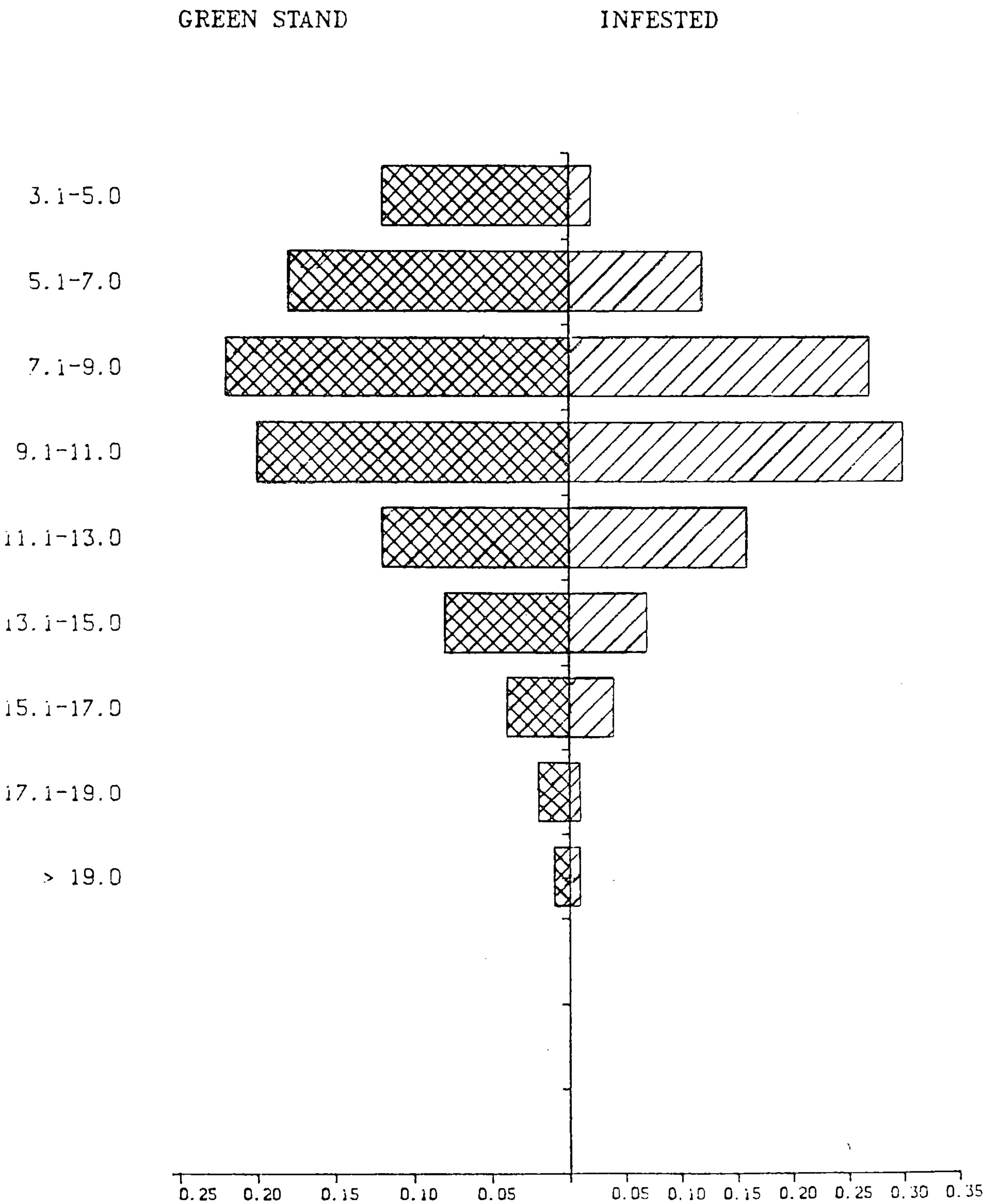


Figure 4. Probability Distributions by Diameter Class for Green Stand in 1979 and Infested Trees, 1979-81, Volcanic Mountains

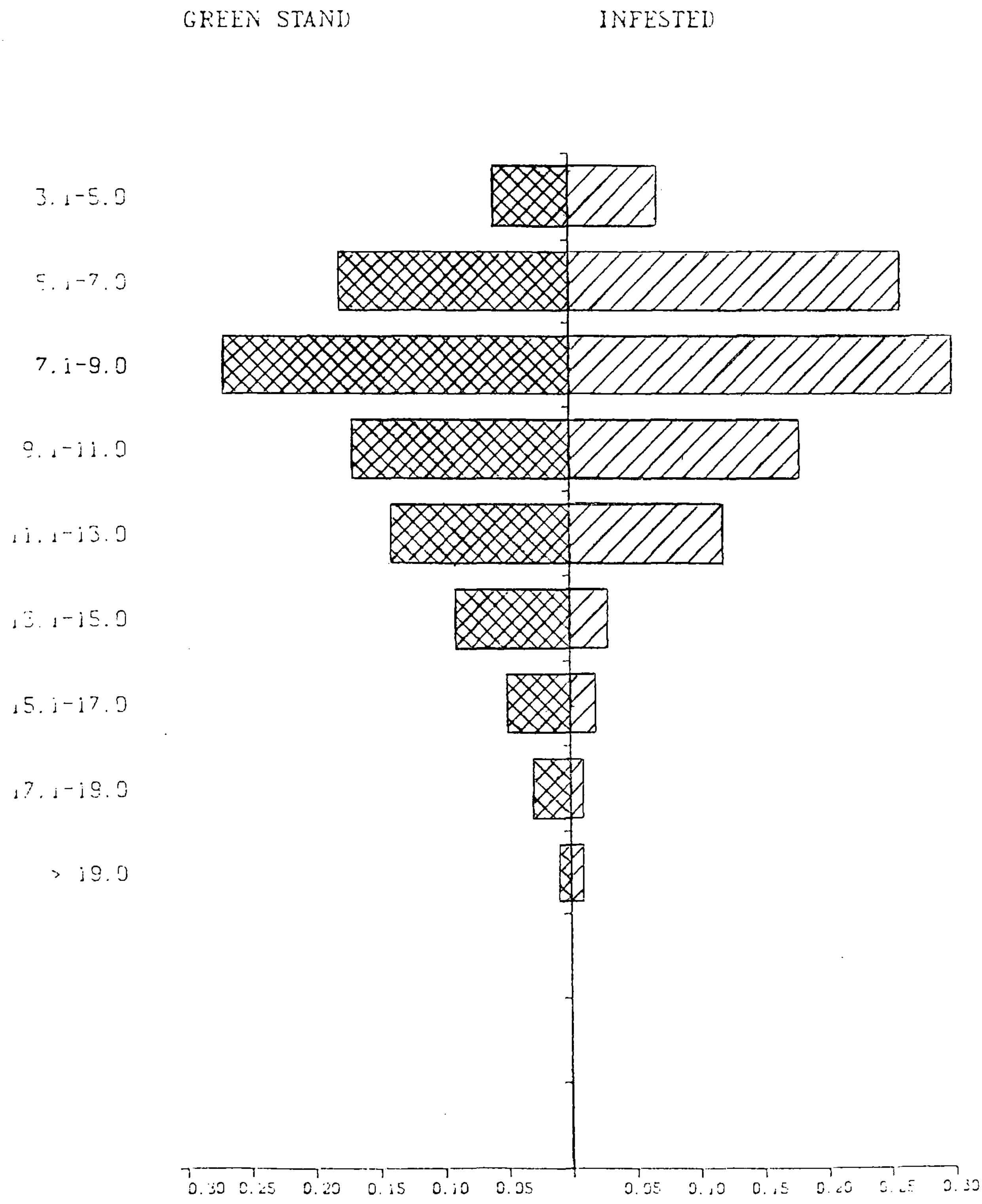


Figure 5. Probability Distributions by Diameter Class for Green Stand in 1979 and Infested Trees, 1979-81, Crystalline Basin

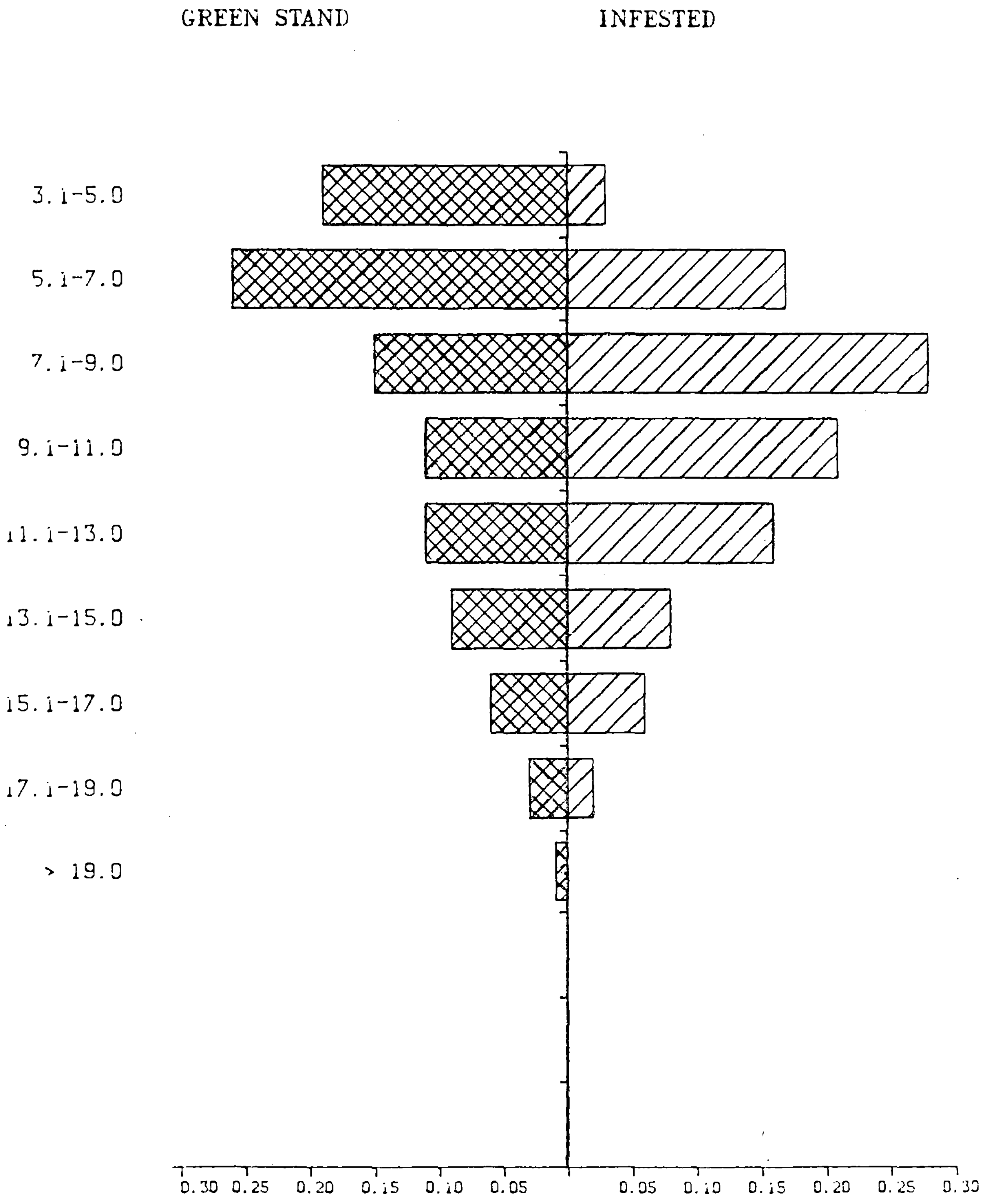


Table 4. Diameter Ranges by Geologic Strata where the Probability of Attack Exceeds the Probability of Occurrence of Green Trees

Geologic Strata	Diameter Range (inches)	Probability	
		Green Stand	Infested
Limestone Plateau	7.1 - 13.0	.542	.731
Volcanic Mountains	3.1 - 11.0	.679	.808
Crystalline Basin	7.1 - 13.0	.367	.646

If a direct relationship existed between incidence of attack and increasing diameter, the probability of trees infested should increase in relation to increased diameter. Obviously, this does not happen on any of the geologic strata. Secondly, the relationship is not strictly random. Random attack would produce probabilities for infested trees that would closely mirror the green stand probability distribution. Thirdly, the relationship is not strictly directed. In directed attack, a diameter class or classes would contain all the infested trees with the remaining diameter classes having a zero, or near zero, probability of attack. On the Limestone Plateau ca. 73% of all infested trees are found in the diameter range of 7.1 - 13.0 inches. Approximately 54% of the green trees are found in this range. On the Volcanic Mountains ca. 81% of all infested trees are found in the diameter range of 3.1 - 11.0 inches. Approximately 68% of the green trees are found in this range. And, on the Crystalline Basin, ca. 65% of all infested trees are found in the diameter range of 7.1 - 13.0 inches. Approximately 37% of the green trees are found in this range. This data indicates that, in general, mountain pine beetle attack is directed. The relationship is random under certain conditions and directed under other conditions. In general terms, beetle attack during the endemic stage appears to be random; during the increasing stage directed; during the epidemic stage random; and, during the final decline directed.3/

Stand structure is an important parameter in stand risk to the mountain pine beetle. The parameters separating 1-story stands and 2-story stands are not defined by Stevens, et al (1980). D. M. Smith (1962) distinguishes between two basic stand forms or structure:

1. Even-aged 4/

2. Uneven-aged

3/ This behavior will be quantified in the final report.

4/ "A stand is considered even-aged if the difference in age between the oldest and youngest trees does not exceed 20 percent of the length of rotation (D. M. Smith, 1962)."

He further classifies uneven-aged as balanced or irregular. These three classifications are depicted in Figure 6 (from D. M. Smith, 1962).

The relationship between stand form or structure and infestation intensity is given in Table 5.

Table 5. Relationship Between Mountain Pine Beetle Infestation Level (1979-81) and Stand Structure (1979) by Geologic Strata. (Note even-aged structure divided into two categories: mean green stand diameter ca. 9.0 and 11.0 inches)

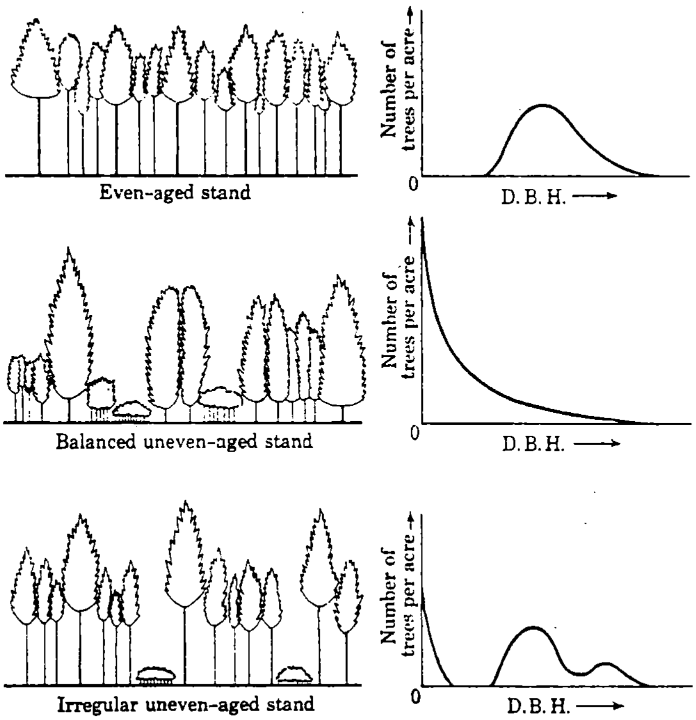
Stand Structure	Limestone Plateau T/A Infested	Volcanic Mountains T/A Infested	Crystalline Basin T/A Infested
Even-aged mean diameter ca. 9.0 inches	43.7	7.7	8.0
Even-aged mean diameter ca. 11.0 inches	18.2	7.5	5.0
Balanced Uneven-aged	4.6	10.7	3.0
Irregular neven-aged	2.3	5.4	2.2
Mean a/	18.3	7.3	4.6

a/ Unequal sample sizes by stand structure. A significant difference ($P < .05$) was found among trees per acre infested on the Limestone Plateau and the Volcanic Mountains; and, the Limestone Plateau and the Crystalline Basin. No significant difference ($P < .05$) was found between trees per acre infested on the Volcanic Mountains and the Crystalline Basin.

Note that the even aged stand structure was divided into two categories: mean green stand diameter ca. 9.0 and 11.0 inches. From Table 5, infestation intensity in trees per acre infested between geologic strata is:

$$\text{Limestone Plateau} > \text{Volcanic Mountains} = \text{Crystalline Basin}$$

Figure 6. Typical examples of three different kinds of age distribution, showing appearance of stands in vertical cross section and corresponding graphs of diameter distribution in terms of number of trees per acre.



Examining individual strata shows the mountain pine beetle behaves similarly on the Limestone Plateau and Crystalline Basin. From Table 5, infestation intensity in trees per acre infested between the four categories of stand structure for the Limestone Plateau and Crystalline Basin is:

Even-aged mean diameter ca. 9.0 inches	>	Even-aged mean diameter ca. 11.0 inches	>	Balanced Uneven-aged	>	Irregular Uneven-aged

and, for the volcanic mountains is:

Balanced Uneven-aged	>	Even-aged mean diameter ca. 9.0 inches		Even-aged mean diameter ca. 11.0 inches	>	Irregular Uneven-aged

Since the balanced uneven-aged stand structure is represented by only one plot on the Limestone Plateau and Volcanic Mountains and three plots on the Crystalline Basin, additional sampling is necessary to clarify this relationship between MPB infestation and stand structure.

<u>Objective 2</u> - Evaluate large scale photographic techniques for risk rating.

In the survey area, 943 2.5-acre photo plots were interpreted. Of the 943 photo plots, 69 were ground truthed (7.3 percent sample). Regression analysis 5/ was used to estimate 1980-infested trees per acre using the following formula:

$$y = 2.14 + 0.78\,x$$

$$r^2 = 0.79$$

where x = infested trees per acre, ground truth
y = estimated infested trees per acre, photo

The mean 1980-infested trees per acre on the Limestone Plateau (2.1 ± 2.2) is significantly greater ($P < .05$) from the Volcanic Mountains (0.8 ± 1.4) and the Crystalline Basin (1.3 ± 1.7). There was no significant difference ($P < .05$) between the Volcanic Mountains and the Crystalline Basin. The same differences were found using only the ground truth data (Ref. Table 4 and Footnote a).

Crown cover in relation to infestation intensity was examined using photo plot data. No relationship was found between crown cover classes within geologic strata or between geologic strata.

Photo information using the parameters selected for this evaluation cannot be used to risk rate ponderosa pine stands in the Black Hills.

5/ Data fit the regression at $P < .05$

Objective 3 - To evaluate other stand/tree parameters which may contribute to stand/tree susceptibility to mountain pine beetle.

The following parameters are being evaluated by Lessard, Cole and Amman:

1. Crown ratio
2. Site index
3. Slope
4. Aspect
5. Elevation
6. Radiation index as a factor of slope, aspect and latitude
7. Diameter distribution as relates to:

    a. stand structure
    b. adult beetle emergence

8. Stand structure

Additional parameters needing evaluation are:

1. Vegetation type
2. Relationship between root diseases and MPB infestation 6/
3. Available moisture within stands
4. Soil types

BUDGET

	ESTIMATED	ACTUAL
(1) Aerial statification, photo acquisition and interpretation	$36,435	20,900
(2) Ground evaluation and data analysis	$72,550	50,600
TOTAL	$108,985	$71,500

6/ Cooperative Study - T. E. Hinds and L. R. Fuller. Black Hills Root Rot-Bark Beetle Association. Field work for this cooperative study is scheduled for September 1982.

REFERENCES CITED

(1) SMITH, D. M. The Practice of Silviculture. John Wiley and Sons, Inc. 1962.

(2) STEVENS, R. E., W. F. McCAMBRIDGE, and C. B. EDMINSTER. 1980. Risk rating guide for mountain pine beetle in Black Hills ponderosa pine. USDA For. Serv. Res. Note RM-385, 2 pp.